OTC 3081

ENVIRONMENTAL ASSESSMENT OF THE BUCCANEER OIL AND GAS FIELD OFF GALVESTON, TEXAS: AN OVERVIEW

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This paper was presented at the 10th Annual OTC in Houston, Tex., May 8-11, 1978. The material is subject to correction by the author. Permission to copy is restricted to an abstract of not more than 300 words.

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INTRODUCTION

An increase in gas and oil exploration and production on the outer continental shelf is expected as the U.S. attempts to reduce its dependency on foreign supplies. As a consequence, a Federal research effort to document environmental conditions before, during, and after oil and gas exploration and production is underway. Much of this research effort consists of baseline investigations that provide essential information on predevelopment conditions. This paper describes the approach used to study environmental conditions existing in an oil and gas field that is fully developed. Findings reported herein are preliminary and are subject to revision.

In 1975, the Galveston Laboratory of the National Marine Fisheries Service (NMFS) was given responsibility for project management of a comparative environmental assessment of an active oil and gas field in the northwestern Gulf of Mexico. The site chosen for the study was the Buccaneer Oil and Gas Field, owned and operated by Shell Oil Co., 32 nautical miles (59 km) south southeast of Galveston, Tex. (Fig. 1). This field was selected as the study area because (1) it has been in development and production since 1960, thus allowing ample time for the development of oilfield-associated marine communities; (2) it is isolated from other fields, thus eliminating or reducing substantially the influence of other fields; (3) it produces oil and gas and releases production brines constituting one of the major sources of contaminants; (4) its location simplifies logistics and reduces the cost of research; and (5) the Texas outer continental shelf area has not been developed fully for oil and gas production, but such development probably will be accelerated in the future.

Objectives of the study are (1) to identify and document the extent and types of biological, chemical, and physical alterations of a marine ecosystem that are associated with development of and production from an oil field; (2) to determine the specific pollutants, their quantity, and their effects on various components of the marine ecosystem; and (3) to develop capabilities to describe and predict fate and effects of oilfield contaminants in major components of the marine ecosystem. The study uses historical and new data to describe and quantify biological, chemical and physical characteristics, and temporal and spatial variations in these characteristics of the environment in Buccaneer field. Objectives are being accomplished through intensive field and laboratory investigations, through statistical analyses and integration of data, and through development of a descriptive and predictive ecosystem model.

Present studies in Buccaneer field are determining the concentration of pollutants in major components of the marine ecosystem, including water, sediments, suspended particulate matter, ichthyoplankton, sessile organisms, pelagic finfishes, and demersal finfishes and macrocrustaceans. Effects of oilfield discharge effluents are being assessed by acute and chronic effects bioassays on shrimp and fishes, by observing alteration of composition and abundance of biotic communities, and by investigating accumulation of contaminants in biotic and abiotic components of the ecosystem. Special attention is being given to food web dynamics and to physicochemical modes of transport of pollutants into and away from the marine ecosystem in the field.

*Reports cited herein were prepared for limited distribution, but copies are available for review at the NMFS Galveston Laboratory, 4700 Avenue U, Galveston, Tex. 77550, or through interlibrary loan.

References and illustrations at end of paper.

Products of this study will include descriptions of changes in the marine environment as related to oil- and gas-field development and production, descriptions of existing environmental conditions, and an ecosystem model for use in predicting probable fate and effects of oil- and gas-field contaminants on the marine ecosystem in the study area.

Following a pilot study late in 1975, the first year (1976-77) of study involved a descriptive survey of environmental and ecosystem variables in the oil and gas field and in adjacent unaltered areas. In the second year of study ending in May 1978, an intensive investigation of environmental and ecosystem variables within the oil and gas field was conducted with a view toward comparison of platforms from which produced brines and other effluents are released with satellite structures (well jackets) from which no effluents are released. The third year of study will concentrate on fate and effects of oil- and gas-field contaminants, stressing concentrations in major ecosystem components (water, sediments, and biota), modes of transport of contaminants, and bioaccumulation of contaminants.

BUCCANEER FIELD

Development

The Buccaneer field was developed by Shell Oil Co. in four federal blocks leased in 1960 and 1968 (Table 1).

Exploratory drilling began about midsummer of 1960 with mobile drilling rigs. When, as a result of exploratory drilling, proper locations for platforms were selected, permanent platforms were constructed. All subsequent drilling and production activities have been conducted from these platforms. A total of 17 structures has been installed: (1) two production platforms, (2) two living quarters platforms associated with the production platforms, and (3) 13 satellite structures (well jackets).

The Buccaneer field reserves are primarily gas, but both gas and oil are produced. In total, 81 wells have been drilled. Of these, 56 were completed and 25 were plugged. Of the 34 wells now active, 31 are gas completions and 3 are oil completions.

Oil Spills

There is no history of major oil spills reported from this field. There have been reported losses of a barrel of oil upward because of mechanical failure of various equipment. From Sept. 1973 through Sept. 1975, a maximum of 6.1 bbl was reported spilled, and three of those barrels were from an unknown source (Table 2).

The platforms are connected by a number of pipelines. Those pipelines 10 in. or greater in diameter are supposedly buried. A pipeline 20 in. in diameter connects the field to shore at Freeport, Tex. The Blue Dolphin Pipeline Co., granted a pipeline permit (No. G1381, Blocks 288 and 296) in 1965, has operated this pipeline since its construction.

Commercial Fishing

The Buccaneer field area apparently was a good shrimping ground before the field was established and apparently has remained so. During commercial shrimping operations, small fishes and other organisms captured with shrimp in the trawls are culled from the catch and returned to the water. These organisms may provide a supplemental food source that would be less easily available to pelagic predatory fish in the absence of commercial fishing.

Recreational Fishing and Diving

The Buccaneer field is a focal point for offshore recreational fishing and diving activity in the area. The recreational fishing craft range in size from boats as small as 16 ft in length to large yachts and sailboats. Some of these craft are marginally seaworthy and in various states of operating efficiency. Fuel slicks occasionally can be observed emanating from such craft in the field. Bottles, paper, food wastes, and other refuse frequently are thrown overboard from pleasure craft. Raw sewage also is discharged from some of these craft.

Transportation

Transportation to, from, and within the Buccaneer field is by seagoing vessel and helicopter. Large packages of freight brought to platforms by vessels are removed by cranes located on the upper decks of the platforms. Solid materials (scrap metal, pipes, valves, tools, batteries, cable, etc.) are sometimes lost overboard near platforms during offloading and other operations, during routine servicing of platforms, or during storms. Depending on their value, these materials either are retrieved by divers or left on the bottom.

APPROACH

Project management responsibility for this study lies with the Galveston Laboratory, NMFS, Southeast Fisheries Center, Galveston, Tex., and is administered through the Office of the Director. Policy definition, coordination with similar projects, and relations with the Environmental Protection Agency are accomplished by the National Oceanic and Atmospheric Administration (NOAA) in Washington, D. C.

A highly integrated multidisciplinary approach is required to achieve objectives of the study. Some of the work is subcontracted with universities and private companies, and the rest is conducted by NMFS laboratories at Galveston, Bay St. Louis, Mississippi, Panama City, Fla., and Narragansett, R. I. Activities of such a wide variety of participants must be coordinated closely. Project management is built around controls exercised by a single executive, the project manager. This allows flexibility to shift resources in accordance with changes in short- and long-term priorities, assures technical integration and scientific integrity of all elements, maintains user-directed issue orientation, induces and maintains expected progress from all participants on a timely basis, provides logistics and vessel support for all participants, elicits feedback from users and beneficiaries of project products, and supports workshops relating to project management and communication of results.

Project management at the Galveston Laboratory provides for over-all scientific and technical

guidance to all participants. Work statements, requests for proposals for scientific and technical aspects, and vessel requirements are developed at the laboratory following guidance from NOAA and EPA. The laboratory assists in evaluation of proposals and selection of contractors, and directs project implementation, including scheduling and overseeing day-to-day operations in the field. It maintains appropriate control over scientific and technical quality of study outputs and deliverables, monitors progress, and collects, assembles, edits and submits required reports to NOAA/EPA on a timely basis. The laboratory also is responsible for financial accountability of the study.

One of the far-reaching results of this study is the systematic collection, processing, storage, retrieval, and archival of a core of marine environmental and ecological data for multiple future uses. A data management system containing the basic policy and procedures, including specific guidelines for data reports, archival and dissemination has been implemented as part of project management. Manuscripts covering the work may be submitted for publication in the NOAA Technical Publication Series or in outside journals.

ACCOMPLISHMENTS

Pilot Study

The goal of the pilot study, conducted by Texas A&M U. in 1975, was to determine whether the Buccaneer field was a suitable site for achieving objectives of the environmental assessment. Objectives of the pilot study were (1) to determine the pattern of distribution of drilling materials used in the field, (2) to determine benthic assemblages of the area, (3) to select an unaltered area similar to the field and suitable as a control for comparison with the field, and (4) to establish a statistically valid sampling strategy to meet requirements of various types of sampling and data collection.

The pilot study[3] showed that the Buccaneer field was a suitable site for achieving objectives of the environmental assessment. A reduction in macrobenthic population density was associated with oily sediments in the vicinity of Platform 288-A. An abnormal ratio of Foraminifera to Nematoda in the meiofaunal population also was associated with the oily sediments, though the population density of meiofauna was not reduced significantly. Much of the hydrocarbon in the sediments was attributed to biogenic origin rather than petroleum. Trace metal concentrations were not abnormally high, except for a few samples containing abnormally high levels of copper (6 ppm), zinc (313 ppm) and lead (42 ppm) not believed to be directly related to petroleum production.

First Year (1976-1977)

The first full year of research was directed toward ecological characterization of the study area. Sampling surveys in the field and adjacent unaltered (control) areas included hydrographic variables, sediments, trace metals, hydrocarbons, organic carbon, and planktonic, benthic, and pelagic faunal communities. A separate survey measured the effects of the Buccaneer field structures on faunal community composition and aggregation. Results of the first year of work were released in Dec. 1977.[4]

Hydrography

Objectives of the hydrographic survey, conducted by NMFS, were to determine and describe (1) the seasonal current patterns (including direction, velocity, and sediment transport capability); and (2) the temperature and salinity regimes in the Buccaneer field area.

From July to October, there was a distinct shift in current direction from southeast offshore to southwest downshore. In August and September, a transition from easterly offshore currents to westerly downshore currents occurred. During late fall and winter, net flow of currents was to the southwest. Temperatures and salinities of waters in and adjacent to the Buccaneer field were affected by air temperatures, surface winds, oceanic currents, and fresh-water inflow, principally from the Galveston Bay-Trinity River complex. Highest temperatures for both surface and bottom waters occurred during August. From August through January, water temperatures decreased with lowest readings occurring in January. Seasonal variations in salinities of surface and bottom waters were generally similar throughout the field area. Lowest salinities occurred during the spring and early summer. Salinities generally increased during late summer and fall with highest salinities for both surface and bottom waters occurring during winter.

Sediments

The objectives of this survey, conducted by Rice U., were to define and describe sediment types, their characteristics, and their distribution in the Buccaneer field as compared with those of an adjacent unaltered area. Analyses were conducted of sediment-sized distribution and trace metal geochemistry, supplemented by clay mineralogy and heavy mineral studies.

Sediments within the study area had highly variable textural properties that reflected scour and redeposition by bottom currents and reworking of ancient sediments. A distinct suspended sediment layer occurred near the bottom within the area during summer. Although the source of this material was not determined, it may serve as a source and sink for chemical contaminants. High resolution seismic profiling along tracks spaced $\frac{1}{4}$ mile apart detected two prominent reflectors that were mapped. These reflectors showed that the area contains faults that play a critical role in influencing surface sediment patterns. A magnetic survey conducted along the same tracks showed that pipelines in Buccaneer field were displaced from a few tens of meters to more than 100 m from their originally mapped locations.

Trace Metals

Objectives of this survey, conducted by Rice U., were (1) to determine levels and pathways of heavy metal pollutants in major components of the marine ecosystem, with some emphasis on increased levels of other trace metals; and (2) to compare these levels in the Buccaneer field with those in a similar but unaltered area. Sediment samples were analyzed for barium, cadmium, cobalt, chromium, copper, iron, mercury, manganese, nickel, lead, strontium, and zinc.

Metal concentrations for bottom sediment samples showed enriched concentrations of lead, zinc, and

strontium near production Platforms 288-A and 288-B and near one of the satellite platforms. Analyses of organisms, including fish, shrimp, squid, ichthyoplankton, and barnacles also were conducted. For the most part, trace metal concentrations in these animals were not abnormally high, with the exception of high cadmium (up to 25 ppm) and strontium (up to 100 ppm) levels in several barnacle specimens. The source of these contaminants was not determined.

Hydrocarbons

The objectives of this survey, conducted by the U. of Houston,[5] were to analyze animals, plants, water, and sediments (1) to determine their hydrocarbon content and (2) to determine if petroleum hydrocarbons were taken up by the physical environment and biota. Samples of oil and condensate produced in the field also were analyzed for comparison with environmental hydrocarbons and those in the biota.

Buccaneer crude oil contained 18 percent n-alkanes, together with branched alkanes and aromatic hydrocarbons. The condensate contained a comparable amount of hydrocarbons, but with relatively greater concentrations of more volatile components. Alkane concentration of the produced brine discharge ranged up to 9 ppm. There was evidence of petroleum-derived n-alkanes (up to 35 ppb) in surface-seawater samples, but alkanes observed in bottom-water samples might have been bacterial in origin. Flesh from barnacles taken 7.5 to 15 m below the surface was free of petroleum, but there was evidence of petroleum alkanes in some flesh samples from barnacles collected near the surface. Most whole barnacle samples (shell and flesh intact) apparently contained petroleum-derived alkanes. Of four species of shrimp examined, only one specimen was found to contain petroleum alkanes.

Organic Carbon

The objective of this survey conducted by the U. of Texas was to determine (1) whether significant changes in sediment organic matter were created by Buccaneer field development and production, and (2) the depth and extent of sediment organic matter originating from Buccaneer field drilling and production activities. Methods used included determination of stable carbon-isotope ratio (delta ^{13}C), determination of total organic carbon, and ^{14}C dating of sediments cores.

There was evidence of erosion of sediments in the field, with erosion predominating over deposition, indicating that any carbonaceous pollutants likely would not accumulate inside the field. The isotopic distribution pattern suggested deposition of hydrocarbons or associated carbon pollutants, but this was inconsistent with radiocarbon dating, which indicated that erosion rather than deposition had occurred within the field.

Ichthyoplankton

The objective of this survey, conducted by NMFS[1] was to determine the species composition, abundance, and distribution of ichthyoplankton eggs and larvae in the Buccaneer field and similar unaltered areas. NMFS marine resource monitoring, analysis, and prediction (MARMAP) sampling procedures were used. The Buccaneer field and adjacent waters were shown to be highly productive. The Engraulidae (anchovies) comprised 38 percent of all larvae collected. Other major groups collected were the Gobiidae (gobies), Bothidae (flatfishes), Carangidae (jacks and scads), and Sciaenidae (drums). The highest abundance of larvae occurred during August and the highest abundance of eggs occurred during May. The lowest abundance of larvae occurred in February. The study area appears to be a major spawning ground for callionymids, clupeids, engraulids, scombrids, sciaenids and soleids. Larvae of little tuna, scaled sardine (Harengula jaguana), thread herring (Opisthonema oglinum), sardine (Sardinella sp.), and silver perch (Bairdiella chrysura) were caught only in the oil field. The Buccaneer field structures apparently serve as artificial reefs, attracting fish that use the area for spawning, feeding, and shelter.

Benthos

It was the objective of this survey conducted by Texas A&M U. to investigate, identify, and describe the living and dead macro-benthic and meiobenthic communities of the Buccaneer field area and a similar but unaltered area.

The Polychaeta and Amphipoda were the macro-benthic taxa containing the greatest number of representatives in the Buccaneer field. Macro-benthic populations around production Platforms 288-A and 288-B were depressed and exhibited high rates of species turnover as compared with most of the remainder of the study area. The production platform sites were characterized by smaller macro-benthic populations of the ubiquitous species and a group of seven species that occurred more frequently and in greater numbers than elsewhere in the field. Dominant meiobenthic taxa were the Nematoda, Foraminifera, and Harpacticoida.

Demersal Finfishes and Macro-Crustaceans

The objective of this survey conducted by NMFS was to determine the species composition, distribution, and abundance of demersal finfishes and macrocrustaceans in the area of Buccaneer field and in two unaltered areas.

Samples were taken with trawls, traps, and by hook and line. The most productive sampling method was trawling, which showed that the dominant species of demersal finfish in decreasing order of abundance were bay whiff (Citharichthys spilopterus), longspine porgy (Stenotomus caprinus), dwarf sandperch (Diplectrum bivittatum), Atlantic croaker (Micropogon undulatus), and pancake batfish (Halieutichthys aculeatus). The dominant crustaceans in decreasing order of abundance were sugar shrimp (Trachypenaeus similis), rock shrimp (Sicyonia brevirostris), chevron shrimp (Sicyonia dorsalis), and brown shrimp (Penaeus aztecus).

The demersal species were taken during four seasons and in all three areas (around platforms and in two unaltered areas sampled by trawling): Sugar shrimp, brown shrimp, and bay whiff. Brown shrimp and sugar shrimp were taken in greater numbers near the platforms than in unaltered areas, while the bay whiff was taken in greater numbers in the unaltered areas. Buccaneer field structures limit commercial trawling operations to open water areas between the

structures, whereas sample trawling using smaller trawls could be conducted closer to these structures. This may have contributed to the higher catches near the structures, which may protect certain species from capture during commercial operations.

Pelagic and Reef Fishes

The objectives of this survey conducted by NMFS were (1) to determine species composition and abundance of pelagic and reef fishes in the Buccaneer field area and in a similar unaltered area, and (2) to measure recreational fishing activity in the field area in terms of total fishing effort, species composition of catch, and catch per unit effort. Sampling methods used included trolling, longlining, gillnetting, and interviewing of recreational fishermen who fished by trolling, bottom-fishing, and diving. Trolling and fishermen interviews provided the most reliable data.

In decreasing order of apparent abundance, the major species caught were red snapper (Lutjanus campechanus), king mackerel (Scomberomorus cavalla), dolphin (Corphaena hippurus), Atlantic spadefish (Chaetodipterus faber), bluefish (Pomatomus saltatrix), little tunny (Euthynnus alletteratus), and cobia (Rachycentron canadum). Gillnetting was not effective. Longlining caught mostly sharks. Catch (number of fish) per hour of troll sampling was highest near production platforms and well jackets, lowest in waters among the oil- and gas-field structures, and intermediate in areas outside the field, suggesting that pelagic fish aggregated around the structures. The highest amount of recreational fishing effort in the Buccaneer field occurred in late August and September. Of the total number of boats observed participating in recreational fishing in the area, 77 percent were engaged in bottom-fishing, 17 percent in trolling, and 6 percent in diving activities. All of the diving effort and 98 percent of the bottom-fishing and trolling effort occurred immediately around production Platforms 288-A and 288-B.

Effects of Structures

The objective of this survey conducted by the U. of Houston was to determine the effects of Buccaneer field structures on the marine ecosystem of the area with regard to (1) seasonal rates of colonization and growth of sessile and nonsessile benthic organisms and communities, (2) aggregation of fish, (3) interrelationships among the various structure-associated ecosystem communities, assemblages, or components, (4) use by sea birds of structure-associated marine fauna for food, and (5) effects of the structures on migratory patterns of birds.

The existing fouling community was dominated by the large barnacle (Balanus tintinnabulum), which provided a matrix of crevices in which other invertebrates were found. Sample surfaces of the structures that were scraped clean were recolonized primarily by hydroids, green algae, and sponges. Atlantic spadefish, sheepshead (Archosargus probatocephalus), crested blenny (Hypleurochilus geminatus), and high hat (Equetus acuminatus) were the predominant resident fishes associated with the structures. Stomach-content analysis indicated that these resident fishes and cocoa damselfish (Eupomacentrus variabilis) fed extensively on the fouling community. The benthic fauna directly below the structures apparently was enriched by the food organisms represented by barnacles and other invertebrates dislodged from the structures. Growth rates of several mollusks were sufficiently rapid to permit adult size to be attained in less than 1 year.

The black tern (Chlidonias niger), accounted for 51 percent of the total number of individual birds observed. Migratory land birds accounted for 12 percent of the total number of individuals but represented 86 percent of the 87 species identified. The remainder of the species and individuals were seasonal residents of the general area. Of the 71 birds observed dead on production Platform 288-A, all were members of the migratory land-bird group. On the basis of this survey it was concluded that the effect of Buccaneer field structures on migratory marine birds was negligible and the effect on resident marine birds seemed beneficial in providing food and resting areas. The effect on migratory land birds seemed detrimental, but the question remains whether these birds would have lived if they had landed on the platform.

Second Year (1977-1978)

In the second year (ending May 1978) of study of the Buccaneer field, emphasis was placed on investigation of the field area, stressing comparisons between structures (production platforms) from which oilfield effluents were discharged with those (well jackets) from which no effluents were discharged.

Investigations were continued on hydrography; sediments and trace metals; hydrocarbons; ichthyoplankton; pelagic, reef and demersal finfishes, and macro-crustaceans; and effects of structures. The studies of organic carbon and benthos, completed during the first year, were terminated. Additional investigations including bacteria, shrimp bioassays, and ecological modeling were initiated. Results of this work are tentative at this time and represent the first half (ending in Dec. 1977) of the second year of study.

Hydrography

This survey was continued by NMFS. A dye dispersion study was conducted in fall with the soluble fluorescent dye, Rhodamine WT. Rate of dispersion was about seven times greater along a north-south axis than along an east-west axis. Movement of the dye plume was with the wind (toward the north). Based on tidal current predictions of the National Ocean Survey for Galveston Harbor Entrance, transport of the plume was about three times greater when the tidal current reversed from opposing the wind (ebb tide current) to running with the wind (flood tide current). Vertical penetration of the dye was very slow. It is expected that vertical mixing would increase under conditions of strong winds or active overturns.

Based on the results of dye studies, we believe that produced brine and other effluents from production platforms would be carried away from their point sources by surface currents at rates proportional to the currents (up to 700 m/hour) but would remain concentrated in a narrow stream or plume for

some distance yet to be determined.

Sediments and Trace Metals

This work, continued by Rice U., identified six trace metals present in anomalously high concentrations in sediment samples from Buccaneer field: barium, cadmium, nickel, lead, zinc, and strontium. These can be classified into three groups with regard to possible source of contamination: (1) contamination related to metallurgy of drilling structures (cadmium, nickel, lead, and zinc); (2) contamination related to the drilling operations (barium); and (3) contamination related to produced water (strontium). Sediment traps used over a 2-week time period to collect suspended particulate matter, trapped large amounts of organic debris including barnacle molts, soft tissue, algae, fish scales and bone, shell fragments and bryozoans. Materials collected in sediment trap tubes showed marked changes in sediment stratigraphy, the most recent deposits containing more detrital clays and silts.

Hydrocarbons

This investigation was continued by the U. of Houston. Below the center of Platform 288-A, the alkane concentration of the sediments was 22 ppm, and a concentration gradient was found to extend outward from this point along transects to the north, south, and east (three directions in which sampling extended). Alkane concentrations were still as high as 0.5 to 0.9 ppm at distances of 23 m from the edge of the platform. A similar distribution was observed for Platform 288-B: 14 ppm below the center of the structure, and 0.1 to 0.6 ppm at the extremities of equivalent transects. The hydrocarbon was remarkably "fresh"; i.e., the concentration maximum in the alkane fraction appeared at n-nonadecane. No oil was found below the well jacket used as a control. Up to 12 ppm alkane was found in a whole barnacle (shell plus intact animal) collected at the surface near the produced water discharge of Platform 288-A. Weathered oil was found in two of 12 brown shrimp, in one of three pink shrimp (P. duorarum), in two of three mantis shrimp (Squilla sp.), and in two of three sugar shrimp (Trachypenaeus similis) analyzed.

Ichthyoplankton

In this survey, continued by NMFS, the Engraulidae (anchovies) were the most abundant larvae in the Buccaneer field together with Sciaenidae, Bothidae, Gobiidae and Clupeidae.

Pelagic, Reef and Demersal Finfishes and Macro-Crustaceans

This investigation (continued by NMFS) found that pelagic and reef fish under production Platform 288-B and a nearby well jacket were more concentrated at 4.6- and 12.2-m depths than near the surface. Dominant species observed were blennies (Hypleurochilus geminatus and Blennius marmoreus), Atlantic spadefish, gray triggerfish (Balistes capriscus), blue runner (Caranx crysos), and sheepshead.

Effects of Structures

This investigation (continued by LGL, Limited-U.S., Inc.) categorized the fouling community of the Buccaneer field into two components, the "habitat formers" (barnacles, bivalve mollusks, etc.) and the "fouling mat" (a sometimes multilayered interspersion of algae, bryozoans, hydroids, sponges, etc.). Each of these two components had an association of cryptic species. The dominant habitat former was the barnacle, Balanus tintinnabulum. The dominant cryptic species associated with the fouling mat included polychaetes, nematodes, and amphipods. Total biomass levels of the fouling community seemed much reduced in the area of the produced water discharge. Population size of Atlantic spadefish was directly proportional to size of structures in the Buccaneer field; i.e., population density was similar at production platforms and a well jacket. In contrast to findings in the first year, it was found that the Atlantic spadefish feeds primarily on meroplankton.

Bacteria

The objective of this investigation, conducted by the U. of Houston, was to determine (1) the total aerobic heterotrophic bacterial population density in the produced water discharge from the two production platforms at the air-water interface, and the water-sediment interface in the vicinity of the platform and at intervals therefrom until baseline levels were reached, (2) the percent of petroleum hydrocarbon degrading bacteria present in each sample, (3) the effect of discharged produced water on growth and viability of bacterial populations, (4) the rate of degradation of hydrocarbon contents of produced water discharge and selected petroleum hydrocarbons, and (5) biomass and production rates for petroleum hydrocarbon degrading bacteria and for total heterotrophic bacteria.

Total colony-forming units enumerated by plate counts showed 200 to 300 bacteria per milliliter of seawater and between 60,000 and 2 million bacteria per gram dry weight of sediment. The distribution in most sampling sites showed a typical shallow-water pattern with the larger microbial numbers found in the sediment and in the water mass near the sediment. There was a greater percentage of oil degraders within the platform area as compared with the control site. Petroleum-degrading bacteria were more common in the upper water, decreasing in number near the bottom. The percentage of oil-degrading bacteria was lowest in the sediment. Dilute produced water did not adversely affect or inhibit the bacteria collected from the platform area. There seemed to be no difference in growth of oilfield isolates in produced water (presumably containing bactericides) collected from the platform discharge and produced water known to be free of added bactericides.

Shrimp Bioassays

The objective of this investigation (conducted by NMFS) was to determine acute toxicity and chronic effects of Buccaneer field produced water on brown shrimp and white shrimp (P. setiferus). At test temperature of $25^{o}\pm1^{o}C$ and concentrations of 10,000 ppm (v/v, produced water discharge/diluent seawater) or greater, all animals died in less than 29 hours. In 3 hours, 100 percent mortality occurred at 500,000 ppm. At 1,000 ppm, only 10 percent died after 96 hours of exposure.

Ecological Modeling

This work (conducted by LGL, Ltd.-U.S., Inc.) was directed toward adaptation and development of a mathematical model to describe and predict fate and effects of oil- and gas-field contaminants.[2,6]

A compartmental model was developed with 10 state variables and four extra-system inputs and outputs (sources and sinks). State variables included floral fouling organisms, faunal fouling organisms, meroplankton, holoplankton, feeders on fouling organisms, plankton feeders, benthos, feeders on benthos, large predators, and particulate matter (sedimental and suspended). Extra-system inputs and outputs included migration, environmental gains and losses, man, and Buccaneer field contaminants. The model was represented mathematically by a series of linear, donor-dependent, differential equations. The equations had the general form: d(biomass)/dt = (income rate)-(loss rate), where t is time. It is expected that a number of the transfers will eventually be expressed as receiver-controlled flows, and some will be nonlinear. Pollutants may impinge upon transfer rates or provide part of the energy flow within the model. The U. of Houston also was engaged in a related modeling activity. This involved development of a conceptual model of sources, distribution and fate, and effects of hydrocarbons in the vicinity of the Buccaneer field. The model was divided into three sections that considered (1) direct inputs of discharges from the field, (2) sulfur-utilizing bacteria, and (3) other biota. The model will be integrated with the more comprehensive ecological model.

PLANS

Third Year (1978-1979)

A review of progress by EPA and NOAA was conducted at a workshop held at Rice U. in Houston, Tex., and at a site visit in Galveston in Dec. 1977 to provide guidance and orientation for the third year of Buccaneer field research. As a consequence, activities in the third year will focus on sources, fate, and effects of offshore oil- and gas-field contaminants. Areas of investigation in the third year will include (1) surficial sediments and suspended particulate matter; (2) shrimp and fish bioassays, (3) pelagic, reef, and demersal finfishes and crustaceans, (4) bacteria, (5) structure-associated communities, (6) circulation patterns, (7) hydrocarbons, biocides and sulfur, (8) heavy metals, (9) fate and effects modeling, and (10) hydrodynamic modeling. Emphasis will be placed on dominant modes of transport of contaminants and dynamics of dominant food webs as they relate to sources, fate, and effects of contaminants. Modeling activities will encompass a detailed and comprehensive analysis, synthesis, and integration of all data generated by this environmental assessment during the first 2 years and part of the third year.

SUMMARY

This multidisciplinary environmental assessment of the Buccaneer field will contribute substantially to the understanding of effects of an offshore oil and gas field on the marine ecosystem. Such understanding is essential to development and extraction of offshore energy reserves in ways that protect, maintain, and preserve offshore marine ecosystems and their important commercial and recreational fisheries resources and in ways that are not harmful to man.

ACKNOWLEDGMENT

This study is supported by the Environmental Protection Agency through Interagency-Energy Agreements No. EPA-IAG-D5-E693-EO, EPA-IAG-D6-E693-EO, and EPA-IAG-D7-E693-EO with the National Oceanic and Atmospheric Administration, U. S. Dept. of Commerce. Participants in the study have been LGL, Limited-U.S., Inc., National Marine Fisheries Service, Rice U., Texas A&M U., U. of Houston, and U. of Texas (Table 3).

We are grateful for the cooperation of Shell Oil Co. during this investigation. The company provided much useful information concerning Buccaneer field structures and operations, provided assistance at no cost in transporting and transferring personnel, supplies and equipment to oilfield structures, and made quarters accommodations available at cost for use by study personnel.

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Table 1. Lease chronology and size for Buccaneer Field

Year	Lease Number	Block Number	Acreage	Hectares
1960	G0709	288	2,790	1,129
1960	G0713	295	4,770	1,930
1960	G0714	296	4,500	1,821
1968	G1783	289	2,610	1,056

Table 2. Reported oil spill chronology and quantity for Buccaneer Field

Date	Source	Amount	
		Barrels	Liters
September 1973	Platform 288-B	0.5	79
November 1973	Unknown	3.0	477
July 1974	Platform 288-B	0.5	79
August 1974	Platform 288-B	1.7	265
September 1975	Platform 288-A	0.2-0.4	38-56
Totals		5.9-6.1	938-956

Table 3. List of work units, principal investigators, and affilitation related to the Buccaneer Field Study

Year	Work Unit	Principal Investigators	Affiliation
1975	Pilot Study	D. Harper, R. Scrudato C. S. Giam	Texas A&M Uni-University, (TAMU), Galveston and College Station, Texas
1976-1977	Hydrography	J. Martin and R. Armstrong	NMFS, Galveston, Texas and Narragansett, R.I.
	Sediments, Trace Metals, and Geophysics	J. Anderson and R. Schwarzer, H. Clark	Rice University Houston, Texas
	Hydrocarbons	B. Middleditch	University of Houston, Houston, Texas
	Organic Carbon	W. Behrens	University of Texas, Port Aransas, Texas
	Ichthyoplankton	J. Finucane	NMFS, Panama City, Florida
	Benthos	D. Harper	TAMU, Galveston, Texas
	Demersal Finfishes and Macro-crustaceans	K. N. Baxter	NMFS, Galveston, Texas
	Pelagic and Reef Fishes	L. Trent	NMFS, Panama City, Florida
	Effects of Structures	G. Allman	U. of Houston Houston, Texas
1977-1978	Hydrography	R. Armstrong	NMFS, Narragansett, Rhode Island
	Sediments and Trace Metals	J. Anderson and R. Schwarzer	Rice University Houston, Texas
1977-1978	Hydrocarcons and Hydrocarbon modeling	B. Middleditch	University of Houston, Houston Texas
	Pelagic, Reef, and Demersal Fishes & Macro-crustaceans	I. Workman	NMFS, Galveston, Texas
	Effects of Structures	B. Gallaway	LGL, Ltd.-U.S., Inc. Bryan, Texas
	Bacteria	R. Sizemore	University of Houston, Galveston, Texas
	Shrimp Bioassays	Z. Zein-Eldin	NMFS, Galveston, Texas
	Ecological Modeling	B. Gallaway	LGL, Ltd.-U.S., Inc. Bryan, Texas

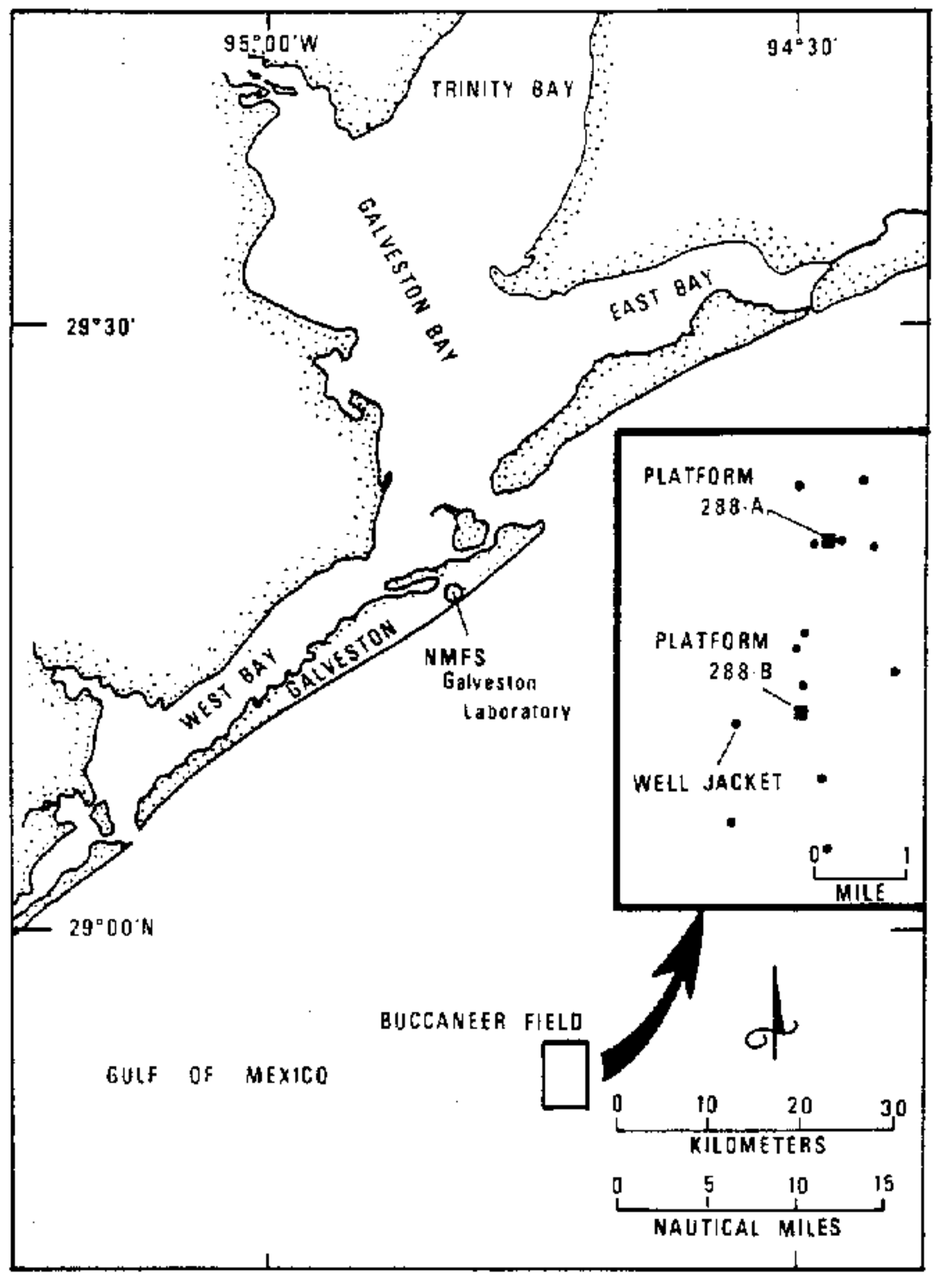

FIG. 1 - LOCATION OF BUCCANEER FIELD.